2022 Lake Willoughby Water Quality Monitoring Results: Lay Monitoring Program and LaRosa Partnership Program

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VT Department of Environmental Conservation, UVM Lake Champlain Sea Grant

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERSHED MANAGEMENT DIVISION
LAKES & PONDS PROGRAM

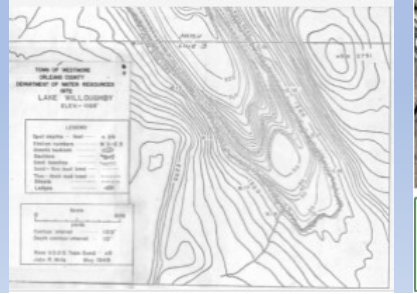
VERMONT LAY MONITORING PROGRAM •1979•

Sea Grant
Lake Champlain

Lay Monitoring Program (LMP) Lake Sampling Overview

- Weekly from Memorial Day to Labor Day (minimum of 8 samples for summer mean):
  - *Basic Sampling:* Measure Secchi disk transparency depth (clarity)
  - *Supplemental Sampling:* Collect water samples with hose at twice Secchi depth that are lab tested for total phosphorus (nutrient) concentration and chlorophyll-a (algae) concentration
  - Complete a lake sampling webform (and report cyanobacteria conditions)

https://dec.vermont.gov/watershed/lakes-ponds/monitor/lay-monitoring



VERMONT

Lake Willoughby Monitoring Station #1

Vermont Agency of Natural Resources

vermont.gov

LEGEND

- Waterbody
- Town Boundary

NOTES

Map created using ANR's Natural Resources Atlas

3,958.0 0 1,979.00 3,958.0 Meters

WGS_1984_Web_Mercator_Auxiliary_Sphere 1" = 6493 Ft. 1cm = 779 Meters

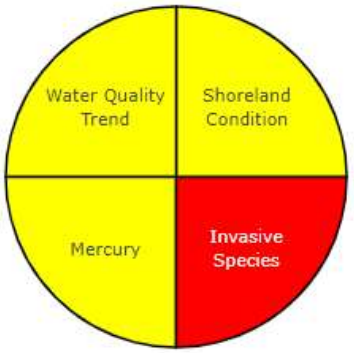
THIS MAP IS NOT TO BE USED FOR NAVIGATION

Vermont Lake Score Card

Lake Willoughby

https://dec.vermont.gov/watershed/lakes-ponds/data-maps/scorecard

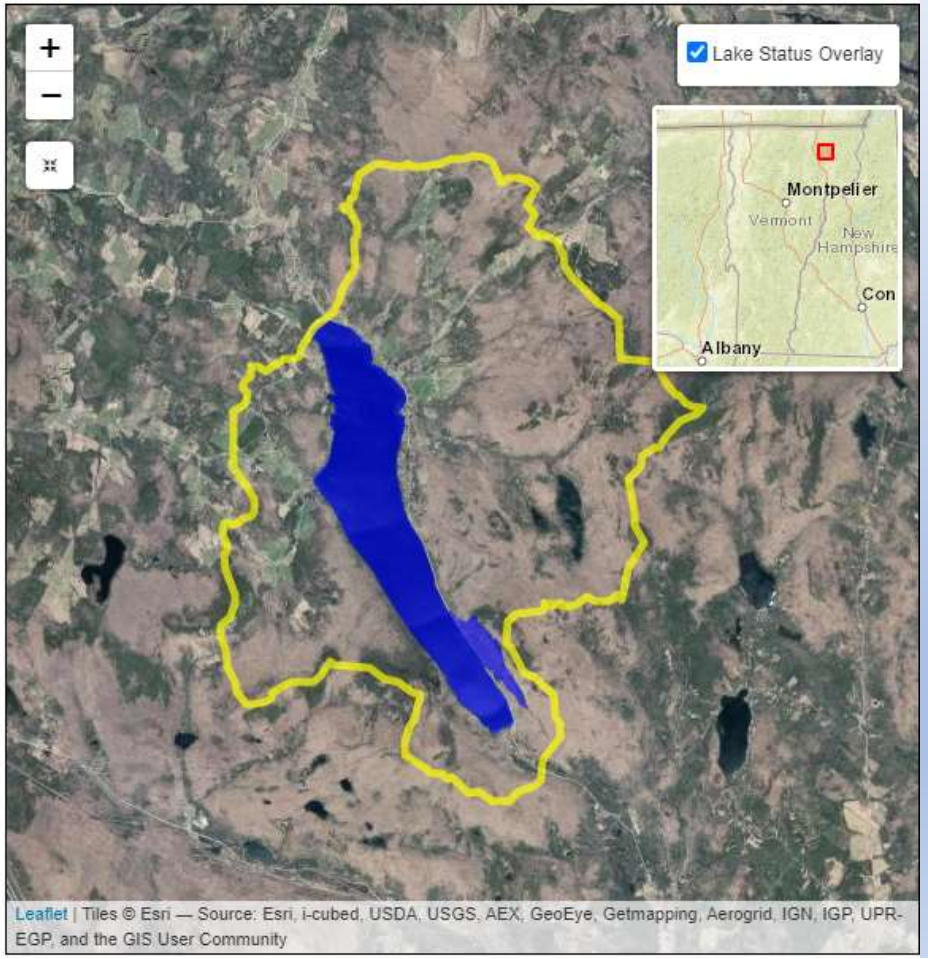
Scores | Water Quality Data | Lake Information



Watershed:	Moderately Disturbed
WQ Standards:	Meets Standards

Color Scoring System
- Good Conditions
- Fair Conditions
- Poor Conditions
- Insufficient Data

Learn How Lakes Are Scored



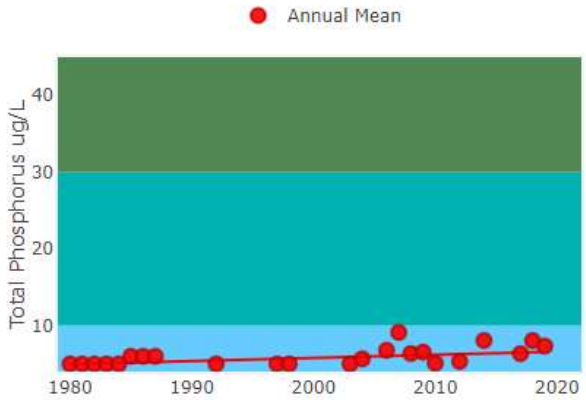
■ Hypereutrophic ■ Eutrophic ■ Mesotrophic ■ Oligotrophic

Click on “Daily Mean” or “Annual Mean” to toggle on or off the data layer.

LAKE WILLOUGHBY SCORE CARD WATER QUALITY ANNUAL MEANS

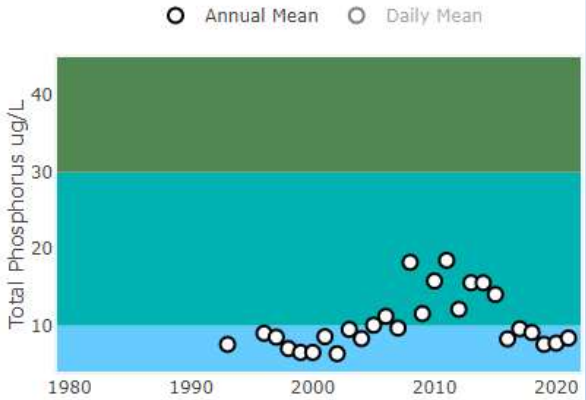
Spring Phosphorus

Trend: Highly Significantly Increasing (p-value=9e-04)



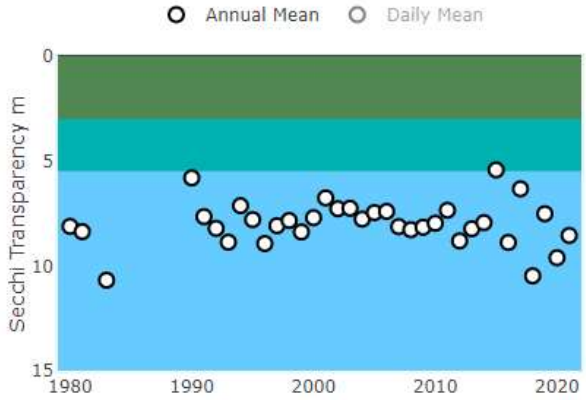
Summer Phosphorus

Trend: Stable (p-value=0.1228)



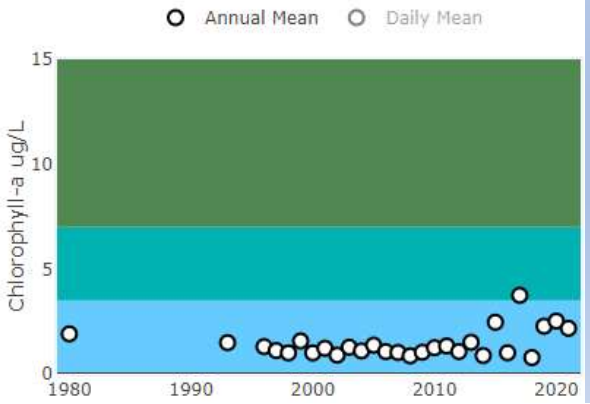
Summer Secchi

Trend: Stable (p-value=0.7014)



Summer Chlorophyll-a

Trend: Stable (p-value=0.4405)



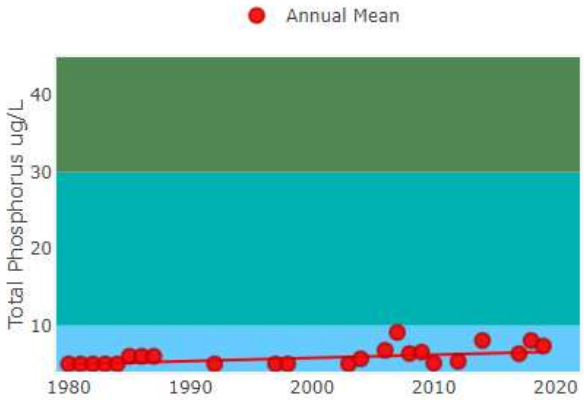
■ Hypereutrophic ■ Eutrophic ■ Mesotrophic ■ Oligotrophic

Click on "Daily Mean" or "Annual Mean" to toggle on or off the data layer.

LAKE WILLOUGHBY SCORE CARD WATER QUALITY ANNUAL RANGE

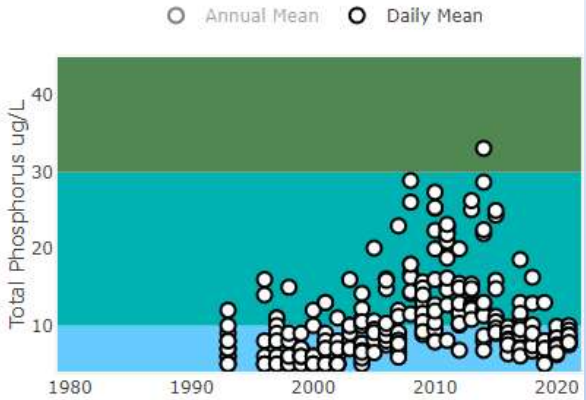
Spring Phosphorus

Trend: Highly Significantly Increasing (p-value=9e-04)



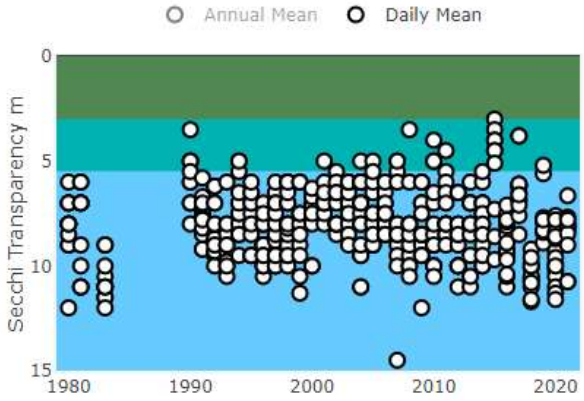
Summer Phosphorus

Trend: Stable (p-value=0.1228)



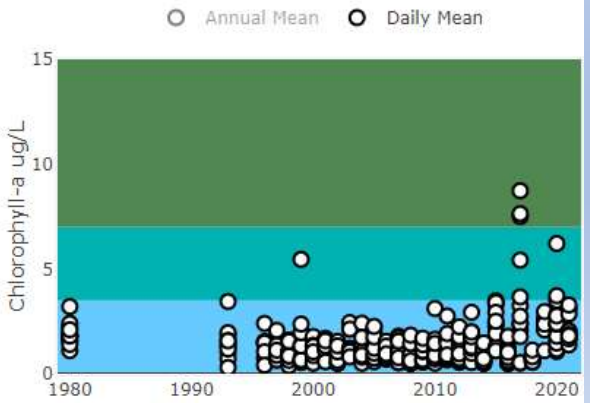
Summer Secchi

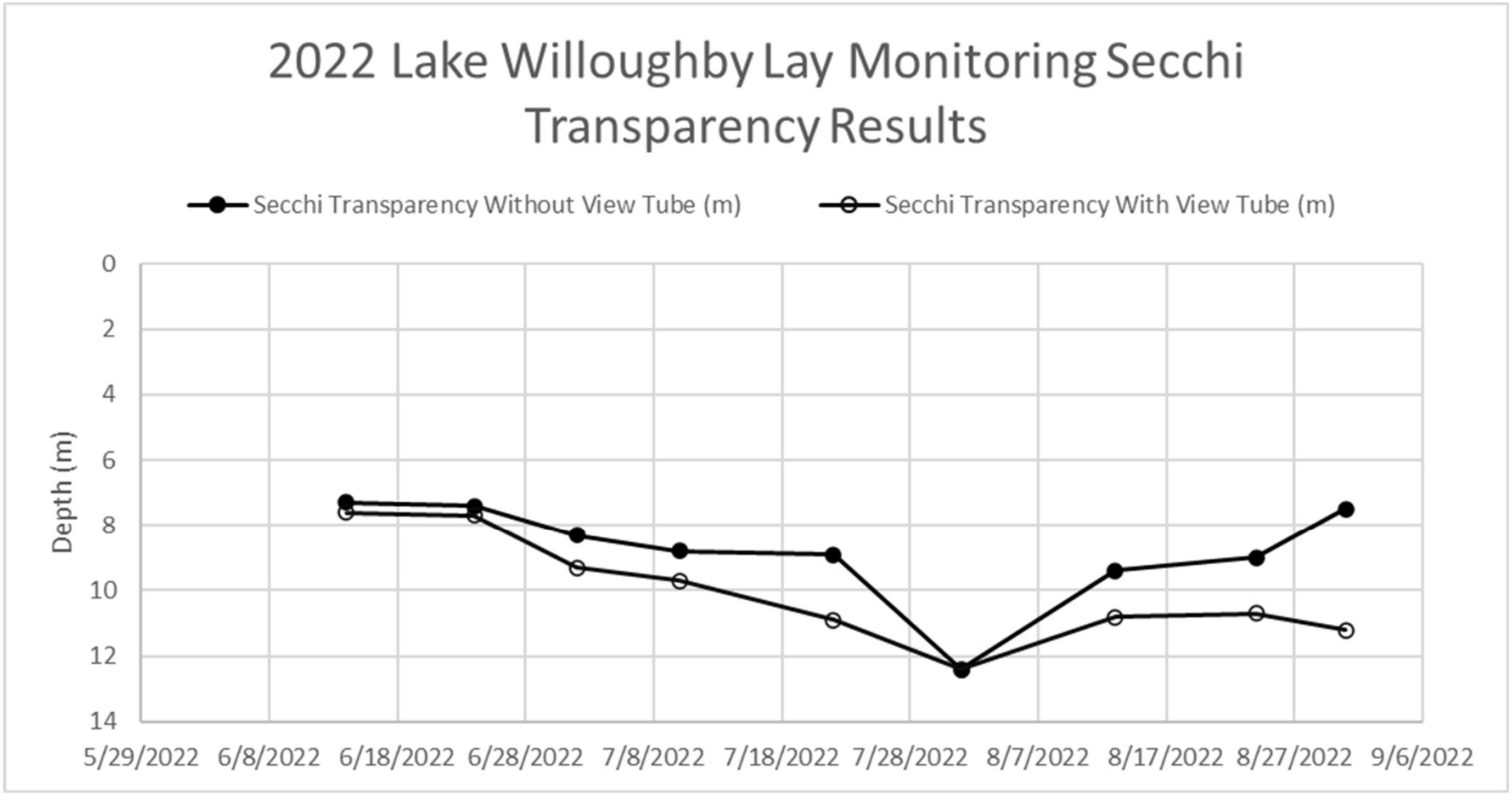
Trend: Stable (p-value=0.7014)

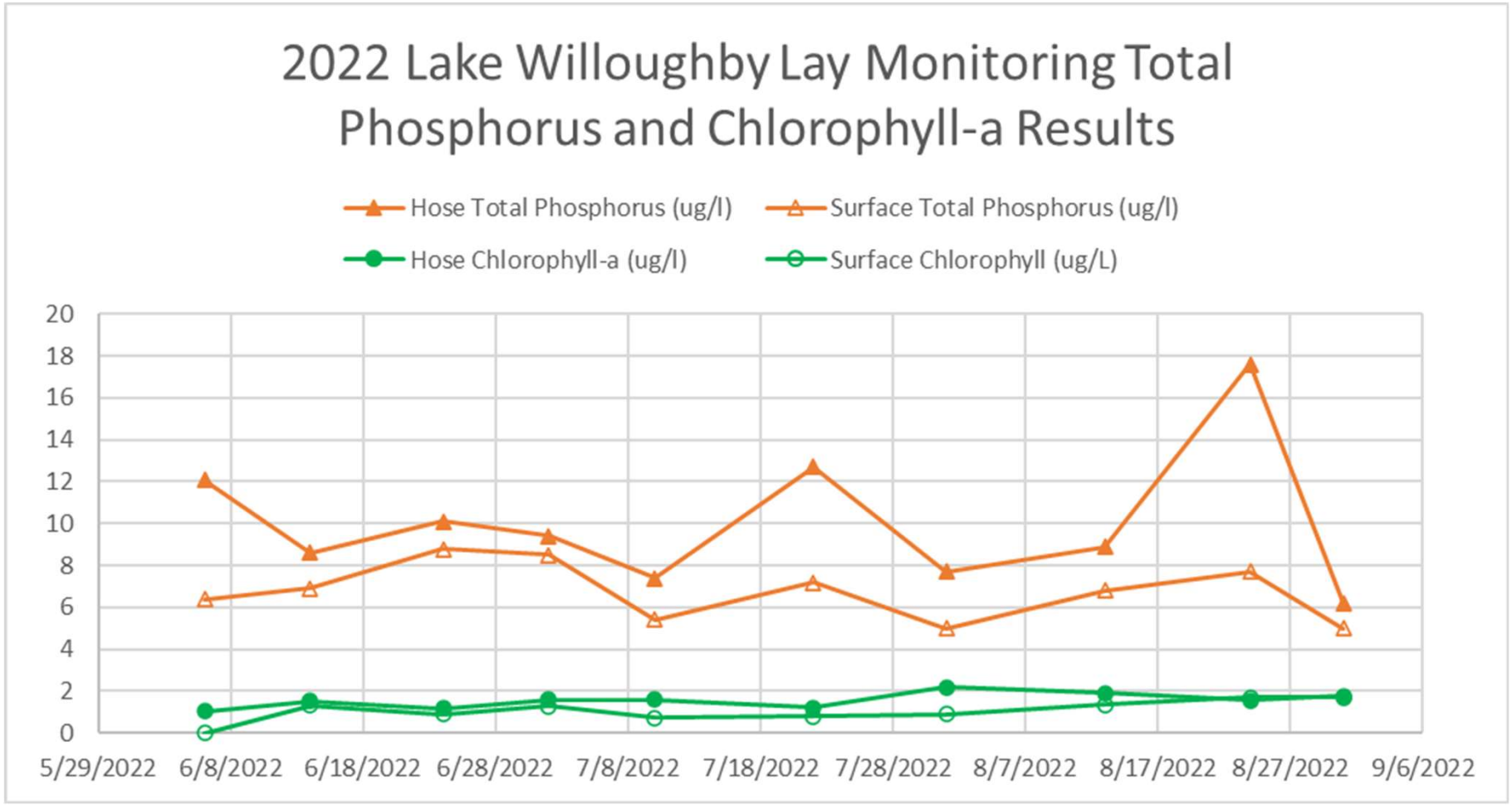


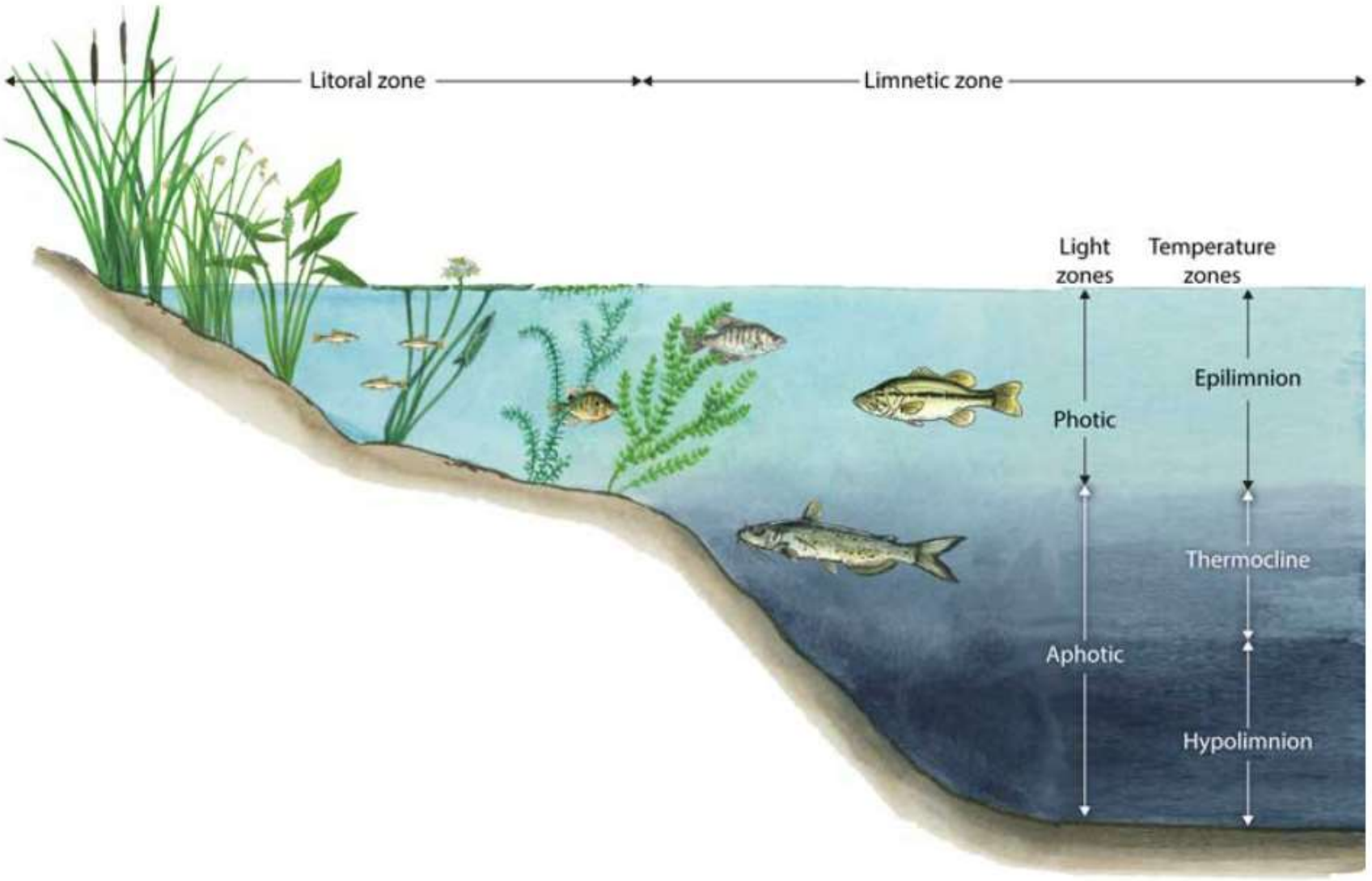
Summer Chlorophyll-a

Trend: Stable (p-value=0.4405)




2022 Lake Willoughby Lay Monitoring Secchi Transparency Results
Secchi Transparency Without View Tube (m)
Secchi Transparency With View Tube (m)
Depth (m)
0
2
4
6
8
10
12
14
5/29/2022
6/8/2022
6/18/2022
6/28/2022
7/8/2022
7/18/2022
7/28/2022
8/7/2022
8/17/2022
8/27/2022
9/6/2022


2022 Lake Willoughby Lay Monitoring Total Phosphorus and Chlorophyll-a Results
Hose Total Phosphorus (ug/l)
Surface Total Phosphorus (ug/l)
Hose Chlorophyll-a (ug/l)
Surface Chlorophyll (ug/L)
20
18
16
14
12
10
8
6
4
2
0
5/29/2022
6/8/2022
6/18/2022
6/28/2022
7/8/2022
7/18/2022
7/28/2022
8/7/2022
8/17/2022
8/27/2022
9/6/2022

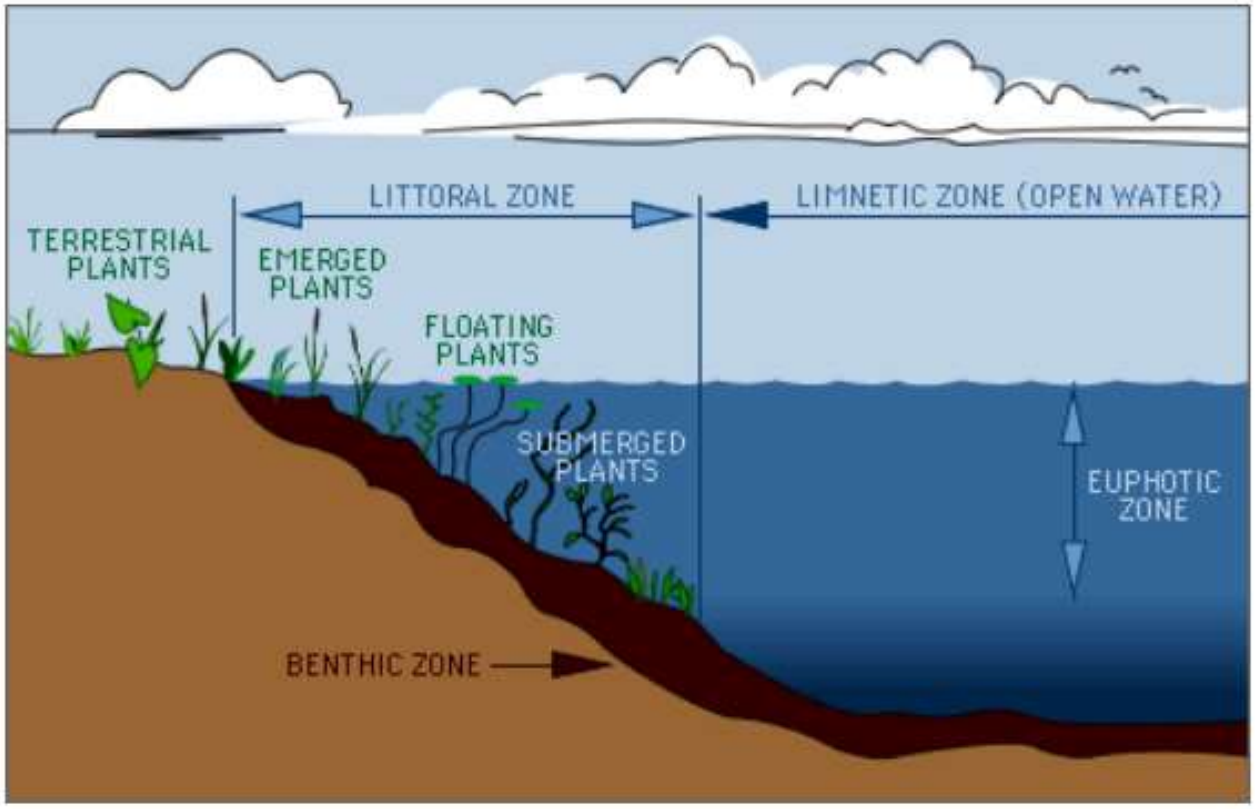


(Image courtesy of Kasco Marine)

https://kascomarine.com/blog/pond-lake-zone-identification/

Lake Zones

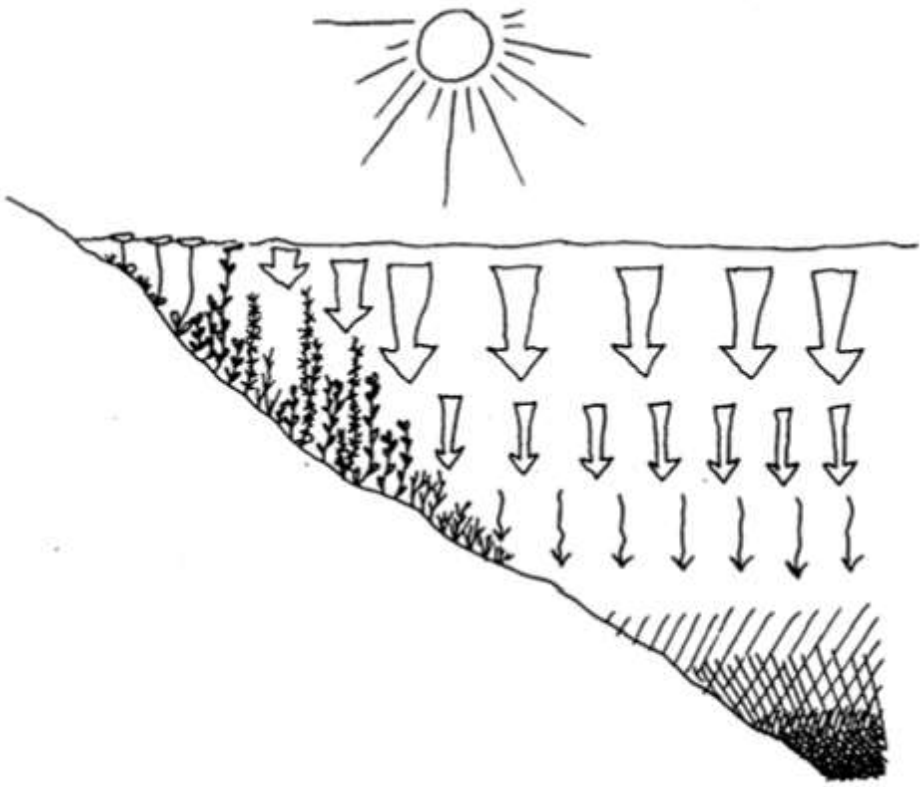
A typical lake has distinct zones of biological communities linked to the physical structure of the lake (Figure 10). The **littoral** zone is the near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (**macrophytes**) to grow. Light levels of about 1% or less of surface values usually define this depth. The 1% light level also defines the **euphotic zone** of the lake, which is the layer from the surface down to the depth where light levels become too low for **photosynthesizers**. In most lakes, the sunlit euphotic zone occurs within the **epilimnion**.



http://waterontheweb.org/under/lakeecology/10_biological_lakezones.html

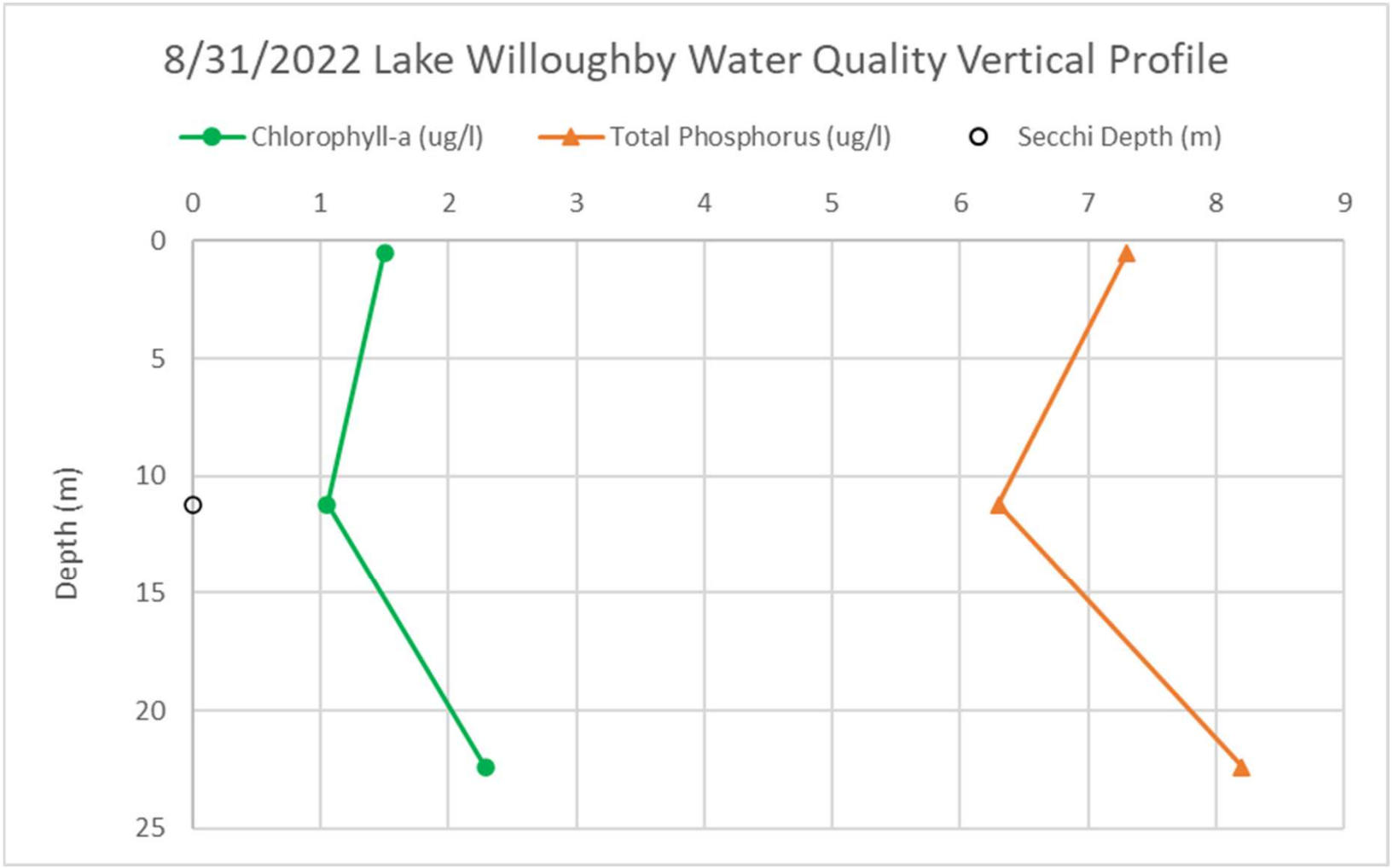
4. *Light*

Plants need light to grow. Many lakes have deep water areas where rooted plants can't get enough light to survive. The maximum depth at which plants grow in a lake depends on the water clarity. In Vermont lakes, plants can generally be found growing out to water depths of 25 feet.



https://dec.vermont.gov/sites/dec/files/wsm/lakes/ans/docs/Lake%20and%20Pond%20Plants%20Booklet.pdf

From Lake Champlain Long-Term Monitoring Protocol:
During stratified conditions, two samples will be obtained, representing the epilimnion and hypolimnion, respectively.
https://dec.vermont.gov/sites/dec/files/wsm/docs/20200605%20LTM%205yr%20QAPP-Workplan.pdf



Sampling Date	Hose Sample Depth (m)	Hose Total Phosphorus (ug/l)	Surface Total Phosphorus (ug/l)	Hose Chlorophyll-a (ug/l)	Surface Chlorophyll (ug/L)	Secchi Transparency Without View Tube (m)	Secchi Transparency With View Tube (m)
6/6/2022		12.1	6.4	1.03	<0.50		
6/14/2022	15.2	8.6	6.9	1.53	1.32	7.3	7.6
6/24/2022	15.4	10.1	8.8	1.16	0.91	7.4	7.7
7/2/2022	18.6	9.4	8.5	1.61	1.29	8.3	9.3
7/10/2022	19.4	7.4	5.4	1.58	0.72	8.8	9.7
7/22/2022	21.8	12.7	7.2	1.22	0.81	8.9	10.9
8/1/2022	22.9	7.7	5	2.2	0.89	12.4	12.4
8/13/2022	21.6	8.9	6.8	1.9	1.36	9.4	10.8
8/24/2022	21.4	17.6	7.7	1.55	1.71	9	10.7
8/31/2022	22.4	6.2	5	1.77	1.7	7.5	11.2
Mean	**19.9**	**10.1**	**6.8**	**1.56**	**1.19**	**8.8**	**10.0**
A1 Criteria	**Euphotic Zone**	**12**	**12**	**2.6**	**2.6**	**5**	**5**

LAKE WILLOUGHBY

Annual Data (Station 1)

Year	Days Sampled	Secchi (m)	Secchi View Tube (m)	Chloro-a (µg/l)	Summer TP (µg/l)	Spring TP (µg/l)
1980	13	8.1		1.9		4.0
1981	11	8.4				4.0
1982						5.0
1983	11	10.7				4.0
1984						5.0
1985						6.0
1986						6.0
1987						6.0
1990	10	5.8				
1991	12	7.6				
1992	13	8.2				5.0
1993	12	8.9		1.5	7.5	
1994	12	7.1				
1995	12	7.8				
1996	15	8.9				
1997	16	8.1		1.1	8.5	4.0
1998	18	7.8		1.0	6.9	3.7
1999	10	8.4		1.6	6.5	
2000	10	7.7		1.0	6.3	
*VT Standard**		*2.6*		*7.0*	*18.0*	

** VT Water Quality Standards Nutrient Criteria for Class B2 Lakes > 20 acres.*

Annual Data (Station 1)

Year	Days Sampled	Secchi (m)	Secchi View Tube (m)	Chloro-a (µg/l)	Summer TP (µg/l)	Spring TP (µg/l)
2001	9	6.8		1.2	8.6	
2002	11	7.3		0.9	6.3	
2003	10	7.3		1.3	9.5	5.0
2004	15	7.8		1.1	8.3	5.7
2005	12	7.5		1.4	10.1	
2006	10	7.4		1.1	11.2	6.8
2007	13	8.1		1.0	9.7	9.1
2008	11	8.3		0.9	18.2	6.4
2009	13	8.2		1.0	11.6	6.5
2010	14	8.0		1.2	15.8	5.1
2011	13	7.3		1.3	18.5	
2012	13	8.8		1.1	12.1	5.3
2013	11	8.2		1.5	15.6	
2014	15	7.9		0.9	15.6	7.9
2015	10	5.4		2.5	14.0	
2016	15	8.9		1.0	8.3	
2017	13	6.3		3.7	9.6	6.3
2018	12	10.5		0.8	9.1	8.0
2019	9	7.5		2.3	7.6	7.3
2020	14	9.6		2.5	7.7	
2021	10		8.5	2.2	8.4	
*VT Standard**		*2.6*		*7.0*	*18.0*	

** VT Water Quality Standards Nutrient Criteria for Class B2 Lakes > 20 acres.*

LaRosa Partnership Program
Tributary Sampling Overview

- Tributaries first sampled in 2021 ~biweekly (8X) from April/May to July/August + ~2 storm events
- 515882-Tr15 Roaring Brk: 30% algae cover at inlet 2 and since biology never lies, worth monitoring this tributary
- 523160-Tr17 Beavers: Includes runoff from farmstead and fields, high TP values in past
- 523161-Tr2Stoney Brk: Includes runoff from farmstead and fields, larger watershed, large delta formed at mouth of trib
- 523162-Tr4 Church: Very high CL readings, interesting for FPR as near site where new parking area and restoration projects are going in
- 523163-Tr5Mill Brk: Upsteam Orleans NRCD Sampling to see impact of farm restoration efforts, could be useful to get a downstream value
- 523164-Tr9SE Beach: Very high TP value, needs follow up

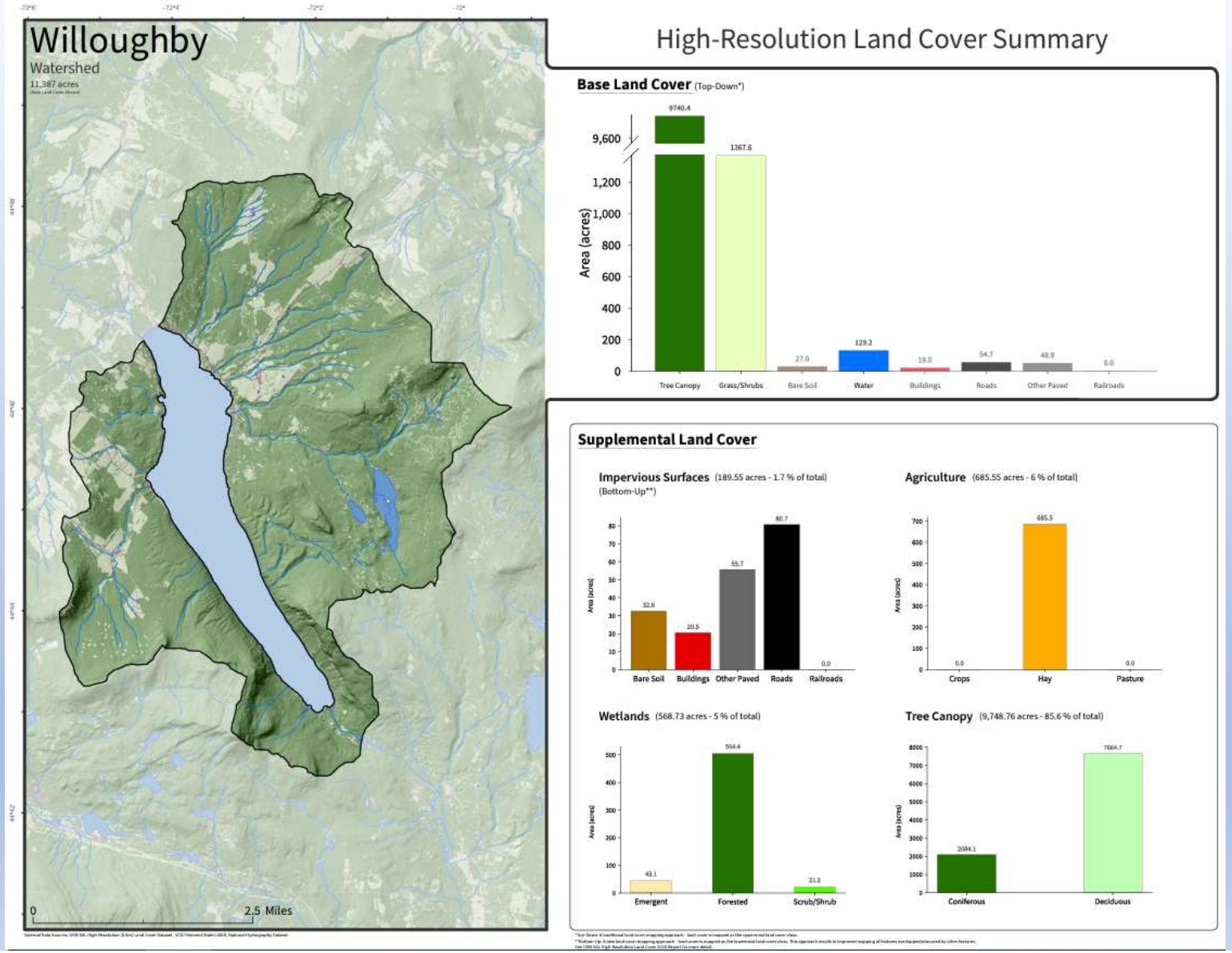
LPP Sample Parameters Overview: Total Phosphorus & Chloride

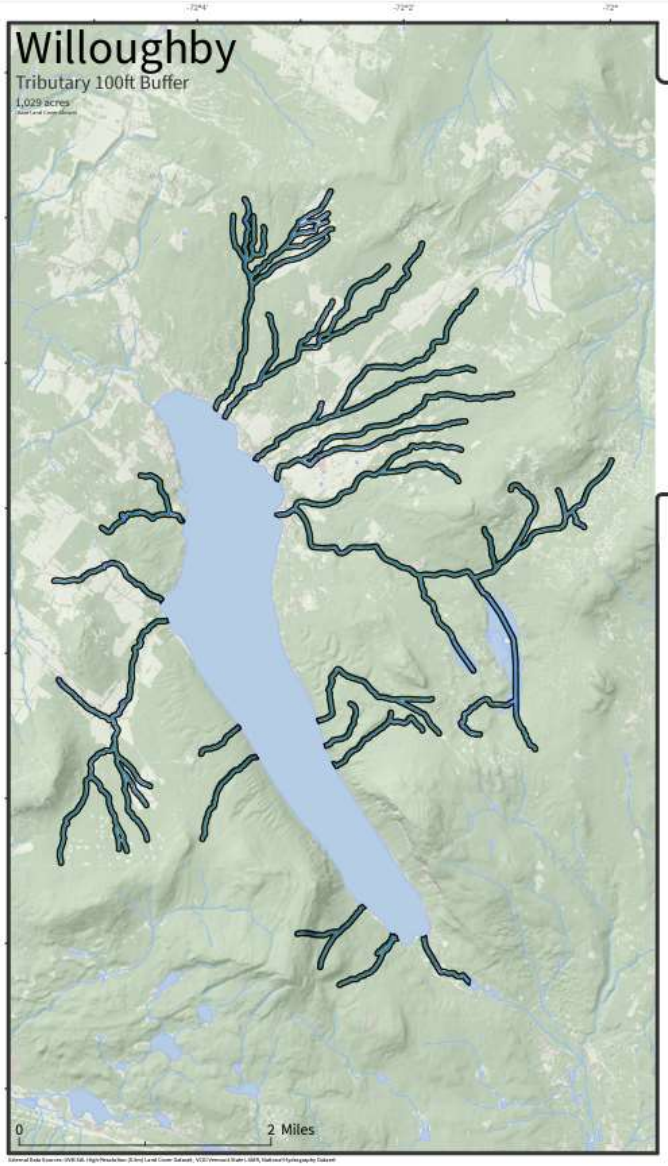
Total Phosphorus

- Sources
  - Developed land runoff, roads, driveways
  - Fertilizers – lawns and agriculture
- Impacts
  - Feeds plants, algae and cyanobacteria
  - Aesthetics, Recreation, Aquatic Life Uses
- Vermont Water Quality Standards Nutrient Criteria for Aquatic Biota Use (+ Biological Criteria)
  - Not to be exceeded at low median monthly flow (baseflow) during June through October
  - 12 ug/L for small high gradient streams (SHG)
  - 15 ug/L for medium high gradient streams (MHG)
  - 27 ug/L for warm-water medium gradient streams and rivers (WWMG)

Total Chloride

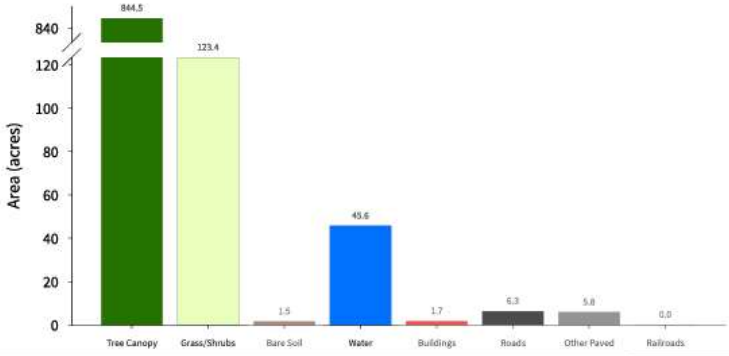
- Sources
  - Road salt
  - Wastewater, water softeners
- Impacts
  - Affects chemical processes of biological organisms
  - Aquatic Life Use
- Vermont Water Quality Standards Chloride Criteria for Aquatic Biota Use
  - 860 mg/L maximum (acute)
  - 230 mg/L average (chronic)
  - Studies show chloride can impact organisms at lower concentrations


Willoughby
Watershed
11,387 acres
0
2.5 Miles
High-Resolution Land Cover Summary
Base Land Cover (Top-Down*)
Area (acres)
9740.4
1367.6
27.0
129.2
19.0
54.7
48.9
0.0
Tree Canopy
Grass/Shrubs
Bare Soil
Water
Buildings
Roads
Other Paved
Railroads
Supplemental Land Cover
Impervious Surfaces (189.55 acres - 1.7 % of total)
(Bottom-Up**)
32.6
20.5
55.7
80.7
0.0
Bare Soil
Buildings
Other Paved
Roads
Railroads
Agriculture (685.55 acres - 6 % of total)
0.0
685.5
0.0
Crops
Hay
Pasture
Wetlands (568.73 acres - 5 % of total)
43.1
504.4
21.2
Emergent
Forested
Scrub/Shrub
Tree Canopy (9,748.76 acres - 85.6 % of total)
2084.1
7664.7
Coniferous
Deciduous



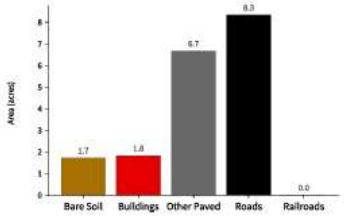
High-Resolution Land Cover Summary

Base Land Cover (Top-Down*)

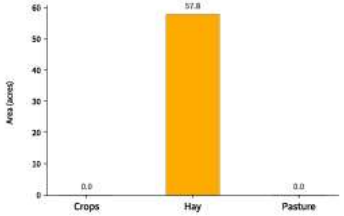


Supplemental Land Cover

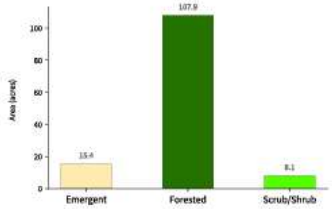
Impervious Surfaces (18.53 acres - 1.8 % of total)
(Bottom-Up**)



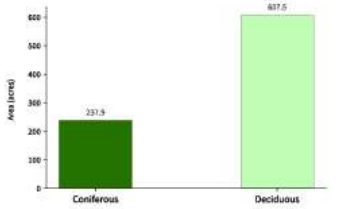
Agriculture (57.81 acres - 5.6 % of total)



Wetlands (131.49 acres - 12.8 % of total)



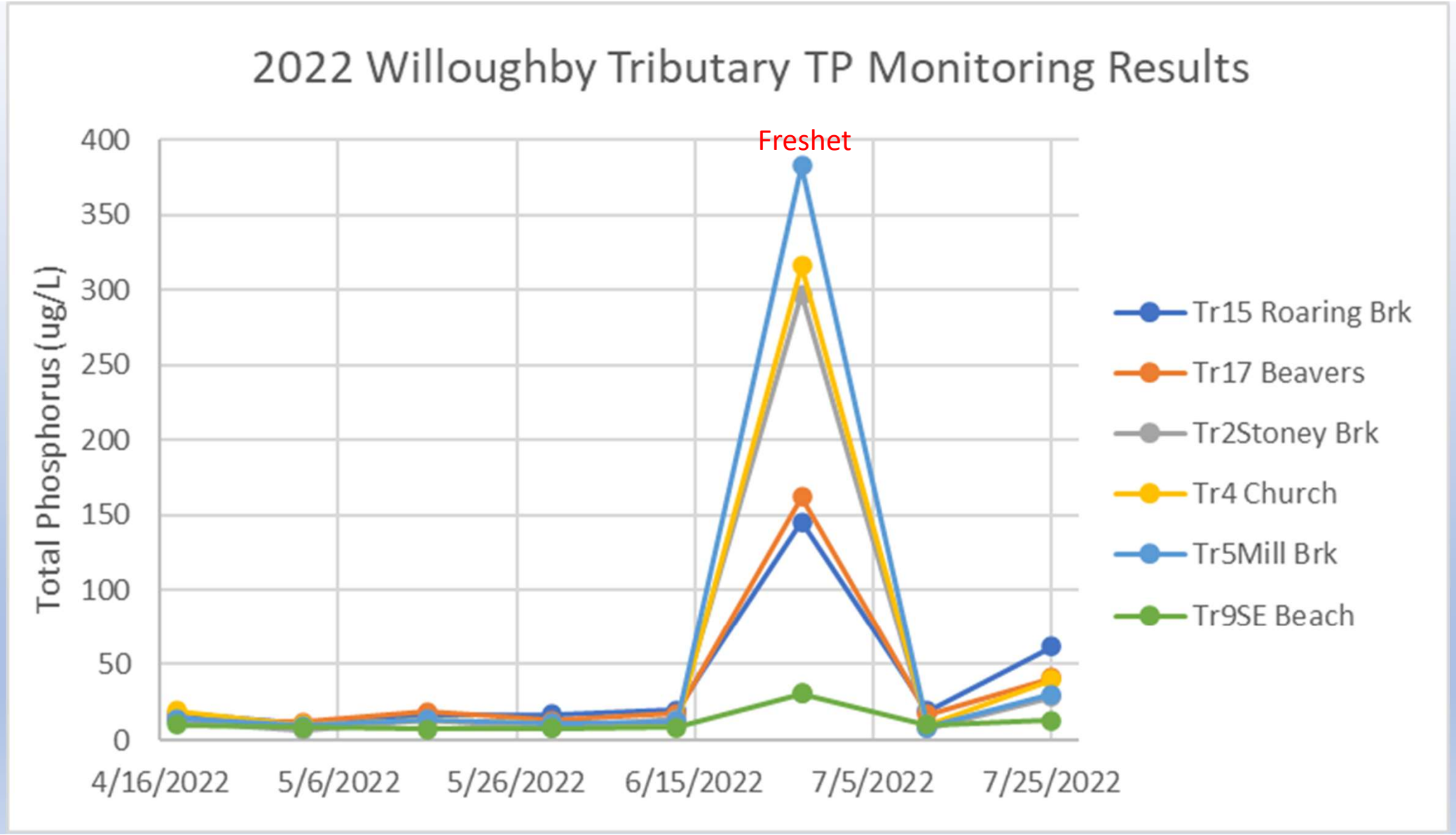
Tree Canopy (845.35 acres - 82.2 % of total)



*Tree Canopy & Grass/Shrubs land cover mapping approach - land cover is mapped as the uppermost land cover class.

**Bottom-Up: Areas land cover mapping approach - land cover is mapped as the lowermost land cover class. This approach results in improved mapping of features overlapped/obscured by other features.

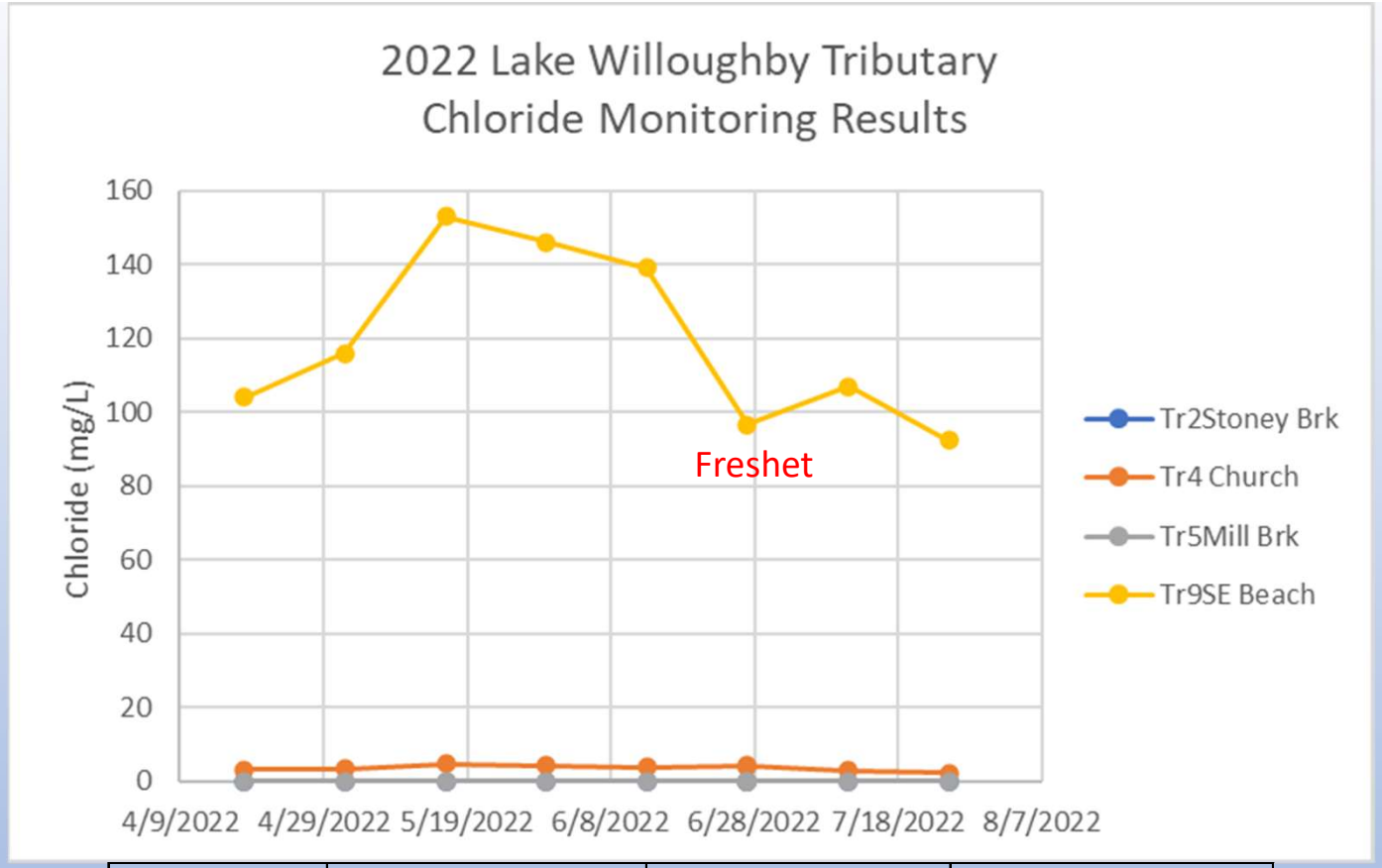
See UVM GIS High-Resolution Land Cover 2016 Report for more detail.


2022 Willoughby Tributary TP Monitoring Results
Freshet
Total Phosphorus (ug/L)
400
350
300
250
200
150
100
50
0
4/16/2022
5/6/2022
5/26/2022
6/15/2022
7/5/2022
7/25/2022
Tr15 Roaring Brk
Tr17 Beavers
Tr2Stoney Brk
Tr4 Church
Tr5Mill Brk
Tr9SE Beach

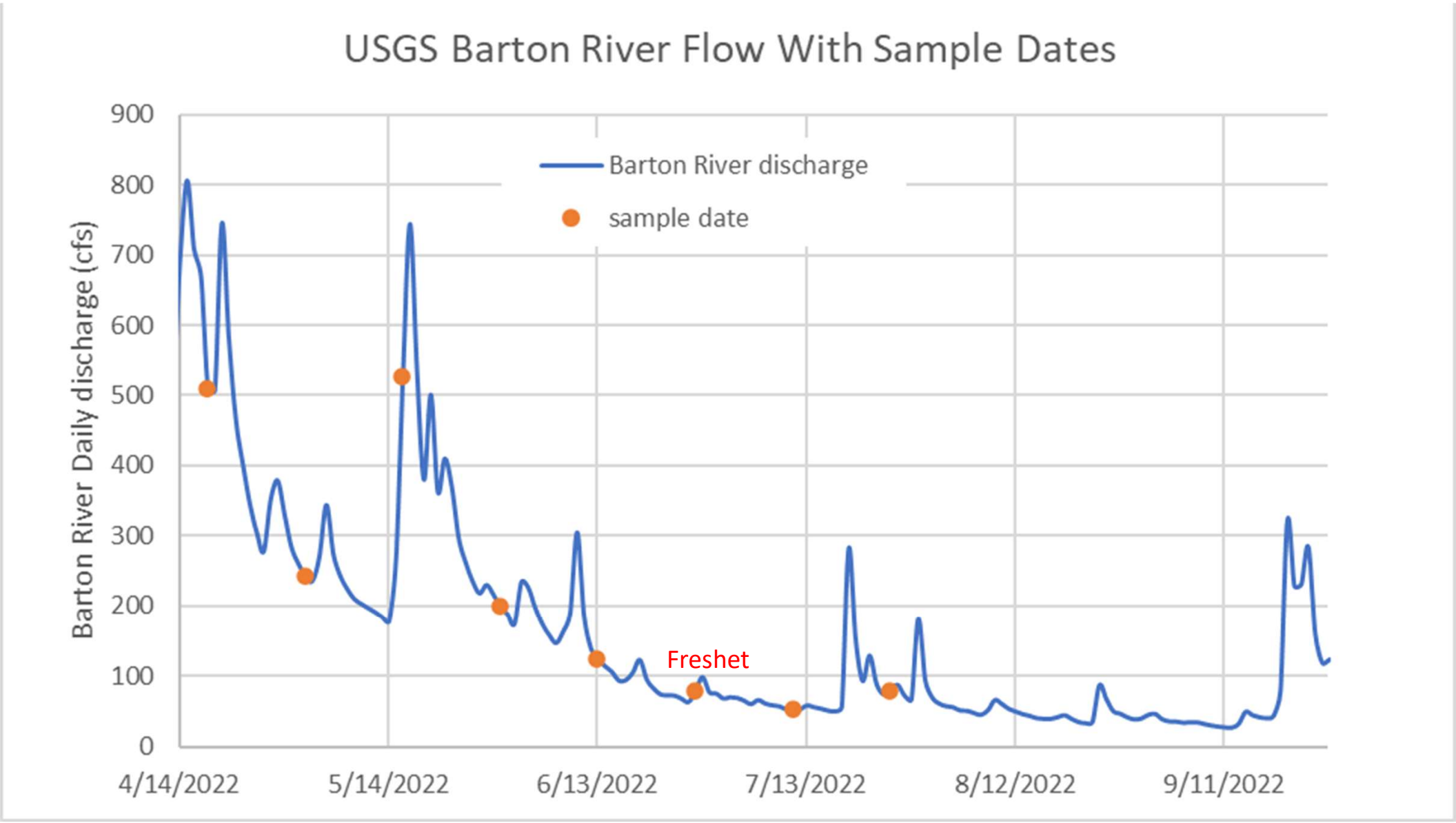
2021-2022 Comparison of Tributary TP Results

Tributary	Minimum TP (ug/L)		Average TP (ug/L)		Maximum TP (ug/L)	
	2022	2021	2022	2021	2022	2021
Tr15 Roaring Brk	10.7	11.6	38.4	48	145	255
Tr17 Beavers	11.5	11.6	36.7	26.7	162	84.6
Tr2Stoney Brk	6.5	7.2	48.4	44.7	297	248
Tr4 Church	9.9	6.1	53.7	42	316	237
Tr5Mill Brk	8.5	7.4	60.3	37.5	383	180
Tr9SE Beach	7.1	6.1	12	9.5	30.8	16.2

Date	Tr15 Roaring Brk	Tr17 Beavers	Tr2Stoney Brk	Tr4 Church	Tr5Mill Brk	Tr9SE Beach
21-22 Ave Base flow	19.6	17.8	11.9	13.0	11.7	8.9
21-22 Ave freshet	127.7	77.6	158.8	167.3	159.1	16.2
21-22 Ave overall	43.7	31.1	46.4	47.3	46.4	10.6



Tributary	Minimum Chloride (mg/L)		Average Chloride (mg/L)		Maximum Chloride (mg/L)	
	2022	2021	2022	2021	2022	2021
Tr15 Roaring Brk	N/A	N/A	N/A	N/A	N/A	N/A
Tr17 Beavers	N/A	N/A	N/A	N/A	N/A	N/A
Tr2Stoney Brk	<2.0	<2.0	<2.0		<2.0	2.0
Tr4 Church	2.2	2.0	3.7	3.4	4.8	4.4
Tr5Mill Brk	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Tr9SE Beach	92.4	42.4	119.3	78.2	153.0	101.0


USGS Barton River Flow With Sample Dates
Barton River Daily discharge (cfs)
900
800
700
600
500
400
300
200
100
0
Barton River discharge
sample date
Freshet
4/14/2022
5/14/2022
6/13/2022
7/13/2022
8/12/2022
9/11/2022

2022 Monitoring Summary & 2023 Next Steps

- Lay Monitoring Program (LMP)
  - 2022 Summary: Hose samples have higher total phosphorus concentrations than surface samples, but surface samples better reflect Secchi depth for class A1 lake
  - 2023 Next Steps: LMP volunteer collects biweekly surface samples and optional deep-water (20 m) samples; LMP staff collects vertical profile data during annual visit; add caffeine testing as human wastewater indicator (i.e. septic systems)
- LaRosa Partnership Program (LPP)
  - 2022 Summary: High TP during Freshet at all sites except 523164-Tr9SE Beach, where there is high chloride
  - 2023 Next Steps: LPP volunteers continue collecting biweekly samples through August at all sites and look upstream for sources